

## ANSWERS: Combustion

organic molecule	equation for complete combustion	equation for <u>in</u> complete combustion
methane	$\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$	$4\text{CH}_4(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 2\text{CO}(\text{g}) + 2\text{C}(\text{s}) + 8\text{H}_2\text{O}(\text{g})$ <i>there are other possibilities by changing moles of CO and C</i>
methanol	$2\text{CH}_3\text{OH}(\text{l}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$	$4\text{CH}_3\text{OH}(\text{l}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}(\text{g}) + 2\text{C}(\text{s}) + 8\text{H}_2\text{O}(\text{g})$ <i>there are other possibilities by changing moles of CO and C</i>
butane	$2\text{C}_4\text{H}_{10}(\text{g}) + 13\text{O}_2(\text{g}) \rightarrow 8\text{CO}_2(\text{g}) + 10\text{H}_2\text{O}(\text{g})$	$\text{C}_4\text{H}_{10}(\text{g}) + 6\text{O}_2(\text{g}) \rightarrow 2\text{CO}(\text{g}) + 2\text{C}(\text{s}) + 5\text{H}_2\text{O}(\text{g})$ <i>there are other possibilities by changing moles of CO and C</i>
pentane	$\text{C}_5\text{H}_{12}(\text{g}) + 8\text{O}_2(\text{g}) \rightarrow 5\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g})$	$2\text{C}_5\text{H}_{12}(\text{g}) + 9\text{O}_2(\text{g}) \rightarrow 6\text{CO}(\text{g}) + 4\text{C}(\text{s}) + 12\text{H}_2\text{O}(\text{g})$ <i>there are other possibilities by changing moles of CO and C</i>
ethanol	$\text{C}_2\text{H}_5\text{OH}(\text{l}) + 3\text{O}_2(\text{g}) \rightarrow 3\text{H}_2\text{O}(\text{g}) + 2\text{CO}_2(\text{g})$	$\text{C}_2\text{H}_5\text{OH}(\text{l}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}(\text{g}) + \text{C}(\text{s}) + 3\text{H}_2\text{O}(\text{g})$ <i>there are other possibilities by changing moles of CO and C</i>
propane	$\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l})$	<div> <math>\text{C}_3\text{H}_8(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow 3\text{C}(\text{s}) + 4\text{H}_2\text{O}(\text{g})</math>  <math>2\text{C}_3\text{H}_8(\text{g}) + 7\text{O}_2(\text{g}) \rightarrow 6\text{CO}(\text{g}) + 8\text{H}_2\text{O}(\text{g})</math> </div> <div> <i>although the following equation should also be accepted</i>  <math>\text{C}_3\text{H}_8(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}(\text{g}) + \text{C}(\text{s}) + 4\text{H}_2\text{O}(\text{g})</math> </div>

*provided in the 2008 assessment schedule*

### Additional questions on combustion

1. Effects on the environment of two combustion products:

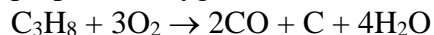
Carbon dioxide gas and water vapour both are greenhouse gases, so they contribute to the greenhouse effect, which leads to global warming due to increased trapping of infra-red radiation / heat and this effects the environment with rising sea levels / melting of polar ice (example).  $\text{CO}_2$  is absorbed by the ocean /

reacts with water in clouds to form (carbonic) acid and this decreases the pH of the ocean affecting marine ecosystems / causes acid rain which can erode buildings, etc.

Carbon particles can produce visual pollution in the environment, e.g. blackening of limestone walls and monuments as carbon particles are deposited on them, or **slow down photosynthesis** due to carbon particles coating leaves which prevents entry / exit of gases and water, or carbon particles in waterways affecting fish and plants, etc.

2. When there is a shortage of oxygen, **incomplete combustion** will occur.

propane + oxygen → carbon + carbon monoxide + water



(accept balanced alternatives with different # CO & C)

Equations may have C and/or CO.

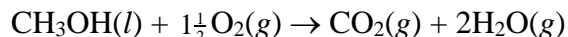
If there was a lack of oxygen:

- the flame would be more yellow – due to specks of C glowing
- black smoke produced – black C
- a black solid (soot) may be seen on the cooking pot – black C
- less heat would be produced (slower cooking) – since there is less oxygen available for complete combustion.

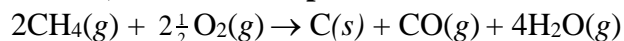
The C (soot) and CO produced during incomplete combustion are harmful to humans. C (soot) can be inhaled and cause respiratory problems and damage the heart; it is also a carcinogen. CO is a poisonous gas as it binds to red blood cells (preventing oxygen binding) and may cause death.

### 3. Describe combustion reactions:

**Methanol** undergoes **complete combustion** (since it burns with an almost invisible flame) to produce **carbon dioxide** gas and **water vapour**.



**Methane** undergoes **incomplete combustion** (since it burns with an orange, probably sooty flame) to produce **carbon** (soot), **carbon monoxide**, (carbon dioxide), and **water vapour**.



(or any appropriate variation of incomplete combustion).

#### Effects of combustion:

**Complete combustion of methanol** produces **carbon dioxide gas and water vapour**, both of which are **greenhouse gases**, so they contribute to the greenhouse effect / global warming.

**Incomplete combustion in methane**, as well as producing carbon dioxide and water vapour, can also produce **carbon particles**, which can cause **asthma** and other respiratory problems in people, **visual pollution in the environment**, eg blackening of limestone walls and monuments, and **slow photosynthesis** by coating leaves. It also produces **carbon monoxide, which is toxic to humans**, and can, in extreme situations, result in death since it **replaces oxygen in the blood supply**.

**4.** Methanol burns completely in plentiful oxygen with a blue / invisible / hot flame. Complete combustion produces  $\text{CO}_2$  and  $\text{H}_2\text{O}$  vapour, which are significant greenhouse gases.  $\text{CO}_2$  and  $\text{H}_2\text{O}$  vapour enhance the greenhouse effect which leads to increased trapping of infra-red radiation in the atmosphere. This leads to climate change and issues around global warming. The ocean absorbs  $\text{CO}_2$  released and this affects seawater chemistry. This can impact on marine food webs at all levels, including a food supply for humans

Octane burns in limited  $\text{O}_2$  with an orange / sooty / cooler flame and soot (C) & CO may be produced as the combustion is incomplete. Carbon is an irritant when inhaled, is a carcinogen, and causes visible pollution. CO is a poisonous gas which, if inhaled will replace the oxygen transporting around the body and ultimately may kill the person.

**5.** Ethanol undergoes complete combustion (with sufficient oxygen) to produce carbon dioxide and water.

Complete combustion produces  $\text{CO}_2$ , which is a greenhouse gas.  $\text{CO}_2$  contributes to the greenhouse effect, which leads to an increase in the amount of infra-red radiation trapped in the atmosphere.

An increase in the concentration of  $\text{CO}_2$  on Earth is believed to lead to global warming and issues around climate change. Some of the issues include extreme weather events, melting of ice at the poles, and decreased biodiversity.

The greenhouse effect is responsible for the Earth's average temperature and is one of the reasons life exists on this planet.

(Water vapour,  $\text{H}_2\text{O}$  gas, has also been shown to contribute to the greenhouse effect. When clouds are present in the atmosphere, more infra-red radiation is trapped.)

**6.** Incomplete combustion produces C (soot) which can be inhaled and cause respiratory problems and damage the heart. Soot is a carcinogen. CO can also be produced which is a poisonous gas as it can replace oxygen's position in red blood cells and cause death.

**7.** Butane is undergoing incomplete combustion as shown by the yellow flame. Incomplete combustion means there is not enough oxygen (insufficient percentage) present in the air for all of the carbon atoms in butane to turn into carbon dioxide. Some or all of it turns into carbon monoxide or carbon particles (soot). The hydrogen atoms react with oxygen to form water. Methanol is undergoing complete combustion as shown by the almost invisible flame. This means there is sufficient oxygen present and all the carbon atoms react with oxygen to form carbon dioxide. The hydrogen atoms here also react with oxygen to form water. Energy is released. Complete combustion is a more efficient producer of energy than incomplete combustion.

**8.** Carbon particles / particulates produced can affect the lungs if breathed in, and can cause respiratory problems including asthma and even lung cancer. (They can also get into the arteries and clog them, leading to heart disease.)

- Carbon particles / particulates can scatter solar radiation. Large amounts of carbon can act as a blanket, blocking solar radiation, reducing efficiency of photosynthesis

- CO is a dangerous gas as it acts like a poison by combining with haemoglobin in the blood. CO forms a stable compound with haemoglobin, preventing oxygen from being carried to the parts of the body that need it. The person dies by suffocation.

- $\text{CO}_2$  is one of the greenhouse gases. It contributes to the greenhouse effect because it causes heat energy to be radiated back to earth and subsequently global warming occurs.

**9.** Propane is undergoing incomplete combustion. It produces CO and/or C (soot) plus water.

Methanol is undergoing complete combustion. It produces CO<sub>2</sub> plus water.

Environmental effect:

The incomplete combustion of propane has the greater effect on the environment:

- carbon particulates produced act as air pollutants which can coat buildings, affecting plants, and human health, etc.
- CO is a dangerous gas
- incomplete combustion involves reduced energy efficiency.

OR

The complete combustion of methanol has the greater effect on the environment because it produces large amounts of CO<sub>2</sub> which contributes to the greenhouse effect and subsequently global warming.

**10.** Methanol reacts with oxygen in both types of combustion. Complete combustion requires plenty of oxygen, producing carbon dioxide and water.

Incomplete combustion occurs when there is insufficient oxygen present for complete combustion to occur, and produces carbon (or soot) / carbon monoxide and water.

**11.** Pentane burns with less complete combustion thus there will be an orange sooty flame producing more carbon, carbon monoxide and less carbon dioxide than ethanol, which will produce more carbon dioxide because its combustion will be more complete. Ethanol will burn with a colourless flame.

OR

If complete combustion only considered then pentane will release more moles of CO<sub>2</sub> and have a larger affect on the environment. Combustion of these fuels leads to more CO<sub>2</sub> in the atmosphere. This contributes to the greenhouse effect which affects global warming. Pentane produces less CO<sub>2</sub> but more C and CO. Carbon (soot) and carbon monoxide in the atmosphere also increases the greenhouse effect as well as being harmful to human health. (Carbon monoxide generally does not hang around long in the air, it reacts with oxygen to form carbon dioxide.)

**12.** Either fuel can be justified as having a larger impact

Propane:

- Incomplete combustion /CO and C / soot (and water)
- $\text{C}_3\text{H}_8 + 2\text{O}_2 \rightarrow 3\text{C} + 4\text{H}_2\text{O}$
- $\text{C}_3\text{H}_8 + 3\frac{1}{2}\text{O}_2 \rightarrow 3\text{CO} + 4\text{H}_2\text{O}$
- Health effect – CO is a poisonous gas that can lead to possible brain damage and death, C can irritate the lungs and lead to respiratory problems.
- Reduced energy efficiency.

Ethanol:

- Complete combustion / CO<sub>2</sub> (and water)
- Health – non toxic  $\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$
- CO<sub>2</sub> is a greenhouse gas, CO<sub>2</sub> produced in enclosed spaces can result in asphyxiation for humans
- Maximum energy efficiency with complete combustion

*Accept equations for incomplete combustion in lieu (or as well as) those of complete combustion.*

**13.** Organic compounds are used as fuels because they burn (combust) easily and produce large amounts of energy. Complete combustion occurs when sufficient oxygen is present for the compound to form carbon dioxide and water. In incomplete combustion, less oxygen is available so some soot (carbon) or carbon monoxide is formed.

**14.** Incomplete combustion produces carbon monoxide and soot as products. Soot can cause irritation of the lungs – respiratory problems (bronchitis, asthma etc). Carbon monoxide can cause decrease in oxygen in blood, leading to possible brain damage and death (due to binding with haemoglobin in red blood cells, so carbon monoxide rather than oxygen is carried around the body).

**15.** Ethanol adds less CO<sub>2</sub> to the atmosphere than the same amount of propane, but more of the ethanol would have to be burned to produce the same amount of energy – the extra CO<sub>2</sub> could increase the problems caused by the greenhouse effect eg global warming, ice cap melting, sea levels rising, droughts etc.

- ethanol cleaner burning, refer to soot, link to particulate health problems.
- propane more likely to undergo incomplete combustion releasing CO, a poisonous gas that can attach to haemoglobin.
- since propane is a gas the filling of cylinders with gas under pressure is more dangerous and in the case of an accident propane could be more likely to cause an explosive combustion reaction.
- ethanol spills can be diluted with water but propane is insoluble in water.
- the social implications of having ethanol available at retail outlets in large quantities could be huge as it is the only alcohol that can be consumed by humans.

*Note: economics not a valid point of comparison here*